

§13. Non-Equilibrium Plasma Diagnostics of Solar Coronal Plasma Verified by Large Helical Device (LHD)

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EUV Imaging Spectrometer (EIS) on board Hinode observes a number of emission lines from iron ions at various ionization stages. Atomic models and their atomic parameters used in these models for solar application could be improved through the experiment of the Large Helical Device (LHD). Independent measurements of plasma temperatures and densities restrict the other plasma parameters in the atomic models in case of the laboratory experiments, which would result to improve the accuracy of these models. The improved models verified by the laboratory experiments will be able to develop new research area in the physics of solar transition region and the mechanisms of chromospheric and coronal heating.¹⁾

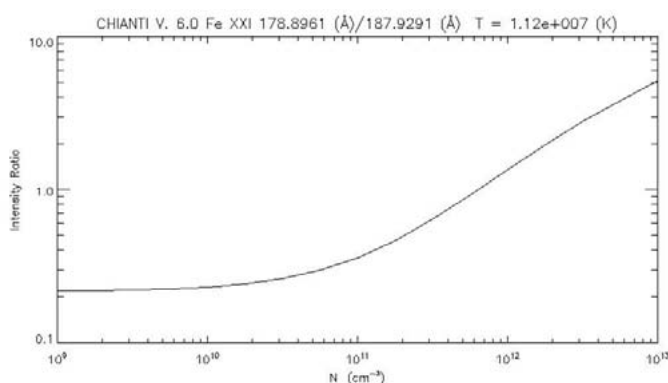


Fig. 1. Density dependence of line intensity ratio of FeXXI $\lambda 178.90 / \lambda 187.93$. It will be very useful to estimate electron density (n_e) of high-temperature plasmas produced in solar corona; $n_e > \text{or} < 10^{11} \text{ cm}^{-3}$.

EIS has been observing FeXVII lines formed in solar active regions. Ne-sequence iron ions, FeXVII, are formed around the temperature of $\log T_e \sim 6.7$, which nearly corresponds to the maximum temperature reached in active regions. EIS observed several weak FeXVII emission lines appearing in its observing wavelengths (170 - 210 Å, 250 - 290 Å), and the line ratios among them were compared with our theoretical calculations. We found that many of them were blended by lower-temperature weak coronal lines, and that the branching ratio of the $2p^5 3p \ ^3S_0$ level to the $2p^5 3s$ levels was wrong roughly by a factor of 2.¹⁾ The intensity ratios of these lines were also successfully measured in LHD at NIFS. EUV spectra were taken by injecting the iron TESPELs (Tracer Encapsulated Solid Pellets) into LHD. An Al filter properly blocked the contribution of the emission

lines in the 2nd order wavelengths, and relatively cool plasma of $T_e \sim 700 \text{ eV}$ was created by the NBI control. The analysis reveals that the intensity ratios of FeXVII $\lambda 204.6 \text{ Å} / \lambda 254.8 \text{ Å}$ are almost consistent to the theoretical value of ~ 1.1 , if we consider the contributions of FeXII and XIII lines blended to the FeXVII $\lambda 204.6 \text{ Å}$ line.²⁾ This fact raised the issue of the in-flight calibration and its degradation of the EIS instrument since the launch of Hinode.³⁾

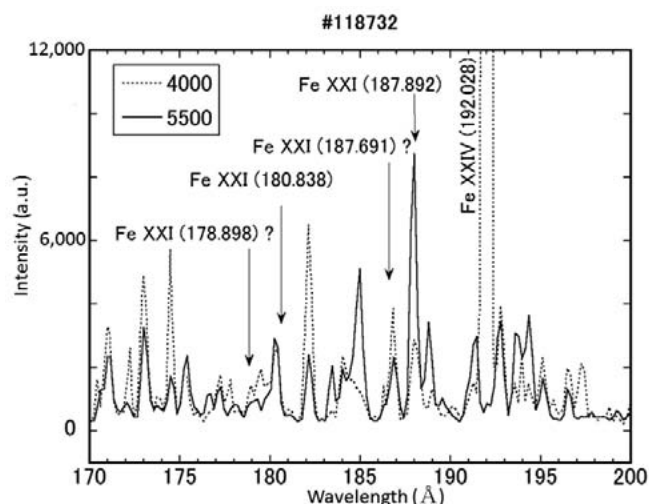


Fig. 2. Iron ion emission lines in EUV wavelengths: A few FeXXI lines seem to appear, when LHD plasma starts to cool down at $t = 5,500 \text{ msec}$.

The next Japanese solar observing mission (nick-named as “Solar-C”)⁴⁾ is now ready to propose to JAXA. One of the candidate payloads for UV/EUV spectroscopic observation (EUVST) will have a capability of observing solar atmospheres in a wider temperature range with higher sensitivity than those of Hinode/EIS. Diagnostic capability with density sensitive line ratios in higher temperatures above $T_e \sim 10^7 \text{ K}$ is of much interest, and it is one of the scientific targets for next cross validation of atomic models and parameters. The LHD measurement for density sensitive line ratios of FeXXI $\lambda 178.90 / \lambda 187.93$ (see Fig. 1) is proposed, and Fig. 2 shows an encouraging spectrum taken during the TESPEL experiment for FeXVII, although the Fe-TESPEL experiment did not take place at LHD/NIFS in FY2013.

- 1) Watanabe, T. et al.: 2013, “Evaluation of Spectroscopic Modeling for Iron Ions and Study on Non-Equilibrium Ionization Phenomena for Solar and LHD Plasmas,” in Proc. ITC22, PFR, Overview Articles Vol. 8, 2501105.
- 2) Murakami, I. et al.: 2014, “Validation of spectroscopic model of Fe ions for non-equilibrium ionization plasma study in LHD and HINODE,” in Proc. ITC23, PFR, Regular Articles Vol. 9, 1401056.
- 3) Del Zanna, G.: 2013, *A&Ap*, 555, A47.
- 4) Solar-C Working Group: 2014, “Solar-C Mission Proposal,” in preparation.